Control of footrot in small ruminants of Nepal

IMPACT ASSESSMENT SERIES 16

CONTROL OF FOOTROT IN SMALL RUMINANTS OF NEPAL

ACIAR Projects AS2/1991/017 and AS2/1996/021

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eSYS Development
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Summary

Footrot, a bacterial disease which attacks the feet of sheep and goats causing lameness and high levels of flock mortality, was endemic in the western districts of Nepal. As a result of the collaborative efforts between Nepalese, Australian and British scientists within ACIAR projects AS2/1991/017 and AS2/1996/021, the virulent form of this disease has been eradicated from the livestock industries of the country. The economic benefits stemming from this achievement are described and quantified in this report.

Over the 1993–2022 period, ACIAR invested $A1.5 million in research designed to improve the management of footrot in Nepal. Based on levels of disease prevalence reported at the beginning of the projects and a probability of the disease spreading to other districts, disease eradication will result in a realised net present value of $A2.8 million. A benefit– cost ratio of 2.9:1 was estimated for the projects, which indicates that for each dollar invested, 2.9 dollars of project benefits will be generated.

Several other countries, such as Bhutan and possibly Australia, could benefit from the footrot vaccination practices developed in these projects. Sensitivity analysis outlined in the concluding section of the report indicates that these benefits could be substantial and their inclusion would increase the value of ACIAR-supported research.

1. Introduction

Footrot is a contagious disease caused by the presence of the bacterium *Dichelobacter nodosus*. Once infected, the animals' hooves are attacked, resulting in pain, lameness and ultimately debilitation. As the disease spreads through a flock, sheep and goat productivity declines as a result of increased mortality, decreased wool production and body weight, and reduced lambing percentage. Within Australia, footrot has been estimated to cost between $A60–100 million per year, owing to the above production constraints, along with treatment costs (Egerton 1991).

The disease was thought to have been introduced into Nepal during the 1960s and had become widespread in the western districts of Kaski, Lamjung and Manang by the early 1990s. Considerable resources were being dedicated to extensive footrot management campaigns based on disease identification and treatment of affected stock — primarily using foot bathing. As a result of this program, the disease was confined to problem areas within these districts, economic losses were reduced and animal populations in some of the footrot area had ceased to decline. However, complete eradication was difficult because of the migratory nature of affected livestock systems, problems accessing livestock owing to the mountainous nature of the region, and difficulty detecting carrier animals (Abington and Rasali 1994).

Considerable footrot control expertise is centred at the University of Sydney in Australia, particularly relating to disease identification and the development of vaccine-based approaches toward disease management. To reduce the impact of footrot in Nepal, ACIAR funded two projects spanning an eight-year period. The series of projects (referred to as PN9117 'Management of footrot in small ruminants in hill districts of Nepal' and AS2/1996/021 'Control of footrot in small ruminants of Nepal — vaccination and sero-surveillance') were initially funded in 1993. The projects involved collaboration between researchers at the Department of Veterinary Science, University of Sydney, Lumle Agricultural Research Centre, Nepal, NSW Agriculture, Monash University and the British Overseas Development Administration (ODA) [now the Department for International Development (DFID)].

In total, $A1.5 million (1996 dollar terms) has been invested in Nepal and Australia across the life of the projects. As a result of these projects, footrot has been eradicated from Nepal, a vaccine-based approach to footrot eradication has been shown to be feasible, considerable research capacity enhancement has occurred and footrot diagnostic tests have been developed.

This report presents a benefit–cost analysis of the above project outputs. Economic benefits are estimated for Nepal within the baseline economic assessment. Initially, project outputs are outlined and are followed by a description of Nepalese sheep and goat (small-ruminant) production systems. The nature of the footrot problem is then described and the economic impacts of footrot eradication calculated. Evaluation results and sensitivity analyses are outlined in the concluding sections of the report.

2. The ACIAR Projects and Their Outputs

The two projects evaluated in this report commenced in July 1993, as project AS2/1991/017. The outputs of this and the following project are described in this section.

2.1 Project AS2/1991/017: Management of Footrot in Small Ruminants in Hill Districts of Nepal

This project involved collaboration between the Lumle Regional Agricultural Research Centre, Nepal, the University of Sydney, Monash University and the British Overseas Development Administration (now DFID). It began in 1993 and had the following major objectives, which were presented as hypotheses in the project documentation:

- isolation and characterisation of the footrot causal organism (*Dichelobacter nodosus*) in Nepal;
- evaluation of the comparative prevalence of footrot in flocks treated with a number of different vaccines; and
- identification of footrot-infected animals using laboratory testing techniques.

The project began with counterparts being trained in laboratory diagnosis of footrot, culture and preliminary characterisation (serotyping, elatase and gelatin gel tests) of *D. nodosus*. Following initial training, field samples were taken and the bacterium characterised into different types, or sero-groups. Vaccines were then tailored for the serogroups found in Nepal and vaccination of animals occurred. Results of the vaccine-based approach were compared with traditional footbathing and antibiotic control of the disease.

2.1.1 Outputs

The following were among the principal project outputs:

- Different types of *Dichelobacter nodosus* in Nepal were characterised following field and laboratory investigations (Ghimire and Egerton 1994; Ghimire et al. 1996). Two virulent isolates were identified and this information was used to formulate vaccines. These findings were disseminated in journal articles and at conferences.

- Following the vaccination of livestock with tailor-made vaccines, there was a dramatic reduction in the prevalence of virulent footrot. In the first season following vaccination, there was a clear reduction in prevalence in the flocks receiving specific vaccine compared with those receiving conventional vaccines. By November 1994 there were no cases of virulent footrot in any of the flocks. Before vaccination, target flocks had up to a 90% virulent footrot prevalence (Whittington and Pradhan 1994). In this year there were also no footrot cases in unvaccinated flocks.

The reason for the reduction in prevalence in both control and vaccinated livestock was unclear. It was postulated that there may have been too few infected animals to initiate infection on the upward migration of livestock to alpine pastures and the disease failed to become established in any flock. Specific vaccination resulted in rapid reduction of prevalence in the population, whereas in previous years recurrence of footrot had been very common after conventional treatments had been applied.

2.2 Project AS2/1996/021: Control of Footrot in Small Ruminants in Nepal — Vaccination and Sero-Surveillance

Following the success of AS2/1991/017, project AS2/1996/021 was implemented in 1997. Project objectives flowed from those in the previous project and similar project collaborators were involved. The project had the following objectives:

- determine the effect of vaccinating against virulent strains by maintaining surveillance of flocks;
- survey flocks in non-endemic zones for evidence of *D. nodosus* infection;
- determine the effects of specific vaccination against mild strains which persist in hill flocks;
- investigate the application of enzyme-linked immunosorbent assay (ELISA) testing to identify the flocks free of virulent strains of *D. nodosus*; and
- establish prevalence of brucellosis and hydatid disease in hill flocks.

3.2.1 Outputs

Key outputs outlined in the project review report (Jordan and Karki 1999) and project completion report (Egerton et al. 2000) included the following:

- A withdrawal of vaccination against virulent strains occurred as multiple surveillance visits were completed and suggested that virulent footrot had been eradicated from the hill flocks.
- Flocks in non-endemic areas were surveyed to ensure that virulent footrot had not spread from known areas of infection. Very many animals were tested and found to be free from virulent forms of the disease. The surveys also revealed that benign footrot occurs in areas where virulent forms of the disease have not been apparent.
- Further livestock disease testing, using ELISA assay procedures, was undertaken. It demonstrated that the hill flocks were free from virulent strains of the disease.
- The prevalence of brucellosis in small ruminants was estimated. Similar investigations for leptospirosis, para-tuberculosis and hydatid disease were not obtained.

3. Realised and Potential Project Outcomes

Footrot was endemic in Nepal before ACIAR projects AS2/1991/017 and AS2/1996/021. The successful deployment of a vaccine-based approach has led to the eradication of the disease in Nepal, and techniques developed in the projects could possibly benefit Australia. Before outlining the economic benefits from footrot eradication, characteristics of small-ruminant production in Nepal are described.

3.1 Small-Ruminant Production in Nepal

Small-ruminant livestock farming contributes about 4% of Nepal's gross domestic product (Bain et al. 2000). Sheep and goats are generally raised as part of mixed farming systems. A principal role of these animals is as a source of organic fertiliser for grain production, and they represent a source of capital for subsistence farmers. The wool of sheep is used in making traditional garments and blankets, while both sheep and goats are a source of supplementary cash income, especially at festival times. A great number of small stock are owned by poor, smallholder farmers who cannot afford to rear large ruminants.

Sheep and goats are raised in the lowlands, mid-hills and Himalayan regions of Nepal (ADB 1993). The lowlands (Terai) are in the south of the country. It is estimated that 14% of sheep and 29% of goats are reared in this region as part of small-scale production systems. The mid-hills lie to the north of the Terai, in the altitude range 800–2400 m above sea level and account for 42% of the Nepalese land area. Many of the large goat-producing regions such as Sinhuli, Kavre and Gorkha are found within the mid-hills region (Figure 1).

The Himalayan region contributes to 35% of the Nepalese land area. Approximately 42% and 14% of the national sheep and goat flocks are raised within this region. The number of sheep in Nepal has been declining in recent years (Figure 2). FAO (2000) reported that the national sheep flock has declined by 40,000 since 1990. On the other hand, goat numbers have been increasing in response to increases in goat meat prices. Goat numbers have increased by 0.88 million since 1990 (FAO 2000).

Indigenous breeds such as the Khari and Terai goats are commonly raised throughout Nepal. Within the hills, the Khari goat is popular, whereas in the lowlands, the Terai goat is more common. Ruminant production is constrained by the availability of feed. The degradation of forests and poor quality of crop residues in many areas is a major constraint on animal production in Nepal (Shresthra and Pradhan 1995). Several other constraints on livestock production noted by Pradhan (2000) are summarised in Table 1.

Figure 1. Map of Nepal and footrot areas (courtesy of the Hill Agriculture Research Project)

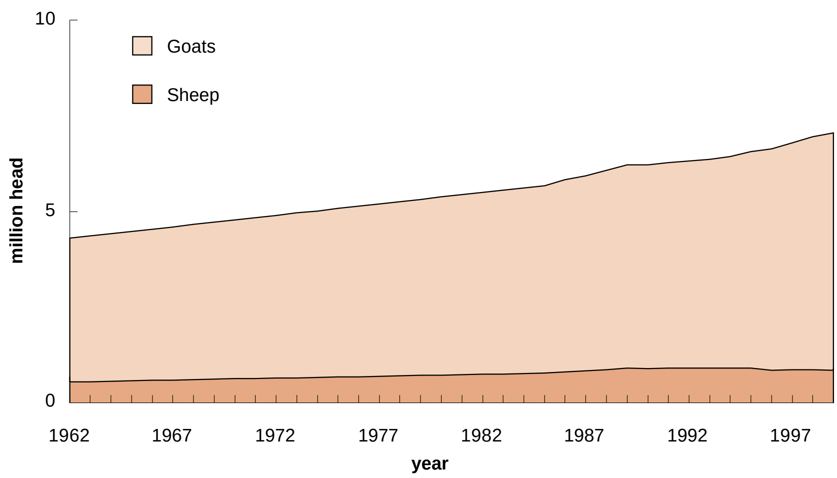

Figure 2. Small ruminant population in Nepal (1962–1999) (source: FAO 2000)

Table 1. Major constraints on small-ruminant production in Nepal (source: from Pradhan 2000)

• Livestock raising is based on the traditional feeding of straws and compound feed formulated with extreme variations in quality.
• The lack of cold storage infrastructure results in the sale of low quality product.
• High interest rates, along with substantial electricity and water tariffs, lead to high operating costs. The small scale of production in Nepal makes competition with Indian livestock produce difficult.
• Animal health, animal breeding and production advisory services are not accessible to all farmers.
• The limited supply of improved genetic material, drugs, vaccines and other inputs discourages farmers from adopting improved management systems.
• Existing institutional structures and facilities are not conducive to encourage private sector provision of products and services.
• Access to livestock insurance is limited.

3.2 The Footrot Problem

Footrot is a contagious disease associated with the presence of the causal organism, *Dichelobacter nodosus*. The bacterium penetrates the skin of a sheep or goat's foot, resulting in pain, lameness and ultimately debilitation (Egerton et al. 1969). In Nepal, footrot was prevalent in migratory sheep and goat flocks of the Kaski, Lamjung and Manang districts. As previously noted, these animals graze fields and forests around villages during winter, and ascend to the alpine pastures where they graze during summer. Footrot transmission is low or nil during winter (December–March) when flocks are around villages (Ghimire 1994). For almost 20 years a concerted attempt had been made to eliminate infection from the flocks during that time of the year. In spite of this effort, the disease recurred during the annual migration to the alpine pastures. The major period of disease transmission is from May onwards. Rainfall is substantial during this month and, correspondingly, high rates of footrot transmission are recorded, particularly in May and June (Ghimire 1994). As the disease spreads through a flock, sheep and goat productivity decline as a result of increased stock mortality, decreased wool production and body weight and reduced lambing percentage.

In Australia, footrot has been estimated to cost between $60–100 million per year (Egerton 1991), owing to the above production constraints, along with treatment costs. Footrot cost estimates were not calculated for Nepal, as most of the production loss data underpinning disease impact studies (see Carmody 1981) have been based on wool production systems in Australia. Small ruminants are raised for meat, wool and manure production in Nepal. However, the disease was considered to be a major constraint on production, as overall flock mortalities were more than 50%

greater within acutely infected flocks (Karki 1994). Farmers considered footrot to be more of a problem than foot and mouth disease, and the movement of lame stock was a time-consuming nuisance for shepherds.

Extensive treatment campaigns were mounted from 1975 onwards to manage the footrot problem (Abington and Rasali 1994). The treatment strategy was based on inspection of individual animals and paring of feet, followed by footbathing in 10% formalin. Infected animals received 70,000 IU procaine penicillin and 70 mg streptomycin per kg liveweight. From 1982, flock monitoring was done in November–January and treatment was carried out between February and June (Karki 1994). The control program was successful as the disease was confined to the problem areas within selected western districts, economic losses were reduced and animal populations in some of the footrot area had ceased to decline. Major constraints hindering complete eradication of the disease included those listed in Table 2.

Table 2. Major constraints hindering complete eradication of virulent forms of the disease (source: from Abington and Rasali 1994)

• Mixing and exchange of livestock between flocks — making quarantine difficult.
• Foci of infection are hidden under the hooves of carrier animals. There is no conclusive method for detecting these animals.
• It was arduous for veterinary teams to reach some of the extremely remote areas of the high hills and to treat or inspect migratory flocks where road infrastructure was limiting.
• Footrot-affected areas were in early monsoon high rainfall zones, making eradication work difficult to carry out. The disease was also spreading at its most rapid rate during this time due to high soil moisture.
• Both shepherds and owners were largely ignorant about the disease, and negligent about implementing methods for effective control.
• Migratory sheep are typically owned by a numbers of farmers. Given the shepherd is only a caretaker, it was difficult for decisions about livestock culling to be undertaken. Culling was never really an option as the animals were too valuable.

3.3 Benefits Associated with Footrot Eradication

Benefits have principally flowed to Nepal as a result of the investments in projects AS2/1991/017 and AS2/1996/021, although some spillover benefits may be captured by farmers and scientists in Bhutan where footrot eradication using vaccine technology is being pursued. Although eradication of virulent footrot was not an original objective of the research, it was in fact achieved. In Australia, footrot control has traditionally relied on disease zoning, quarantine, culling, limited use of vaccines and footbathing of livestock. The large number of serogroups endemic to Australia complicates the use of vaccines in footrot management. However, future research into possible vaccine usage, combined with the success of the project in Nepal, may lead to footrot eradication in Australia using techniques refined within the ACIAR projects. Potential benefits to Australia are explored in the sensitivity analysis that concludes the evaluation.

Before disease eradication, large amounts of scientific and extension input were dedicated to the management of footrot in western Nepal. The treatment and monitoring of infected flocks was arduous work and tied up valuable research expertise and scientific capacity at the Lumle Agricultural Research Centre. Even after 1987, when a shortage of veterinarians and commitments to other research activities resulted in less intensive treatment campaigns (Karki 1994), substantial resources were committed to controlling the disease.

As a result of the management campaigns instituted by the Lumle Agricultural Research Centre, the number of footrot prevalent flocks in the Kaski, Lamjung and Manang districts was reduced from about 120 in the 1970s, to 20 flocks by 1994 (Ghimire and Egerton 1994). In the event that eradication did not occur and resources for monitoring and treatment campaigns were further reduced, the levels of footrot prevalence within currently endemic districts would have increased and the disease could have spread to neighbouring districts. Neighbouring districts including Mustang, Gorkha, Myagdi and Baglung have large sheep and goat populations (330,000), and flocks from Kaski, Lamjung and/or Manang are likely to mix with animals from these districts when in alpine pasture areas.

Flock productivity in disease-affected areas was substantially lower when compared with footrot-free livestock. Karki (1994) noted that flock mortality was 52.7% higher in flocks that were infected at the acute level. An even greater level of mortality and morbidity was thought to be derived from starvation and weight loss. The debilitation of livestock also created difficulties for shepherds, as stock were much more difficult to move as part of routine husbandry practices.

With the eradication of footrot, both treatment costs to contain the disease, and any residual footrot-inflicted mortality and production loss costs are avoided. These groups of benefits comprise the project benefit stream incorporated in the benefit–cost framework. In addition to economic benefits, a number of other benefits can be attributed to the projects. These include the following:

- The presence of footrot caused livestock lameness and mortality, along with inflicting meat production losses and reduced wool output.

The fertility of sheep and goats is also likely to be reduced as males cannot easily mate and the oestrous cycle of breeding ewes is often retarded. These factors lead to a reduction in food production and lessened food security for farming families within footrot endemic areas. Eradication of the disease has removed these impediments on production.

- After harvesting maize crops, and before transplanting winter crops, ruminants are grazed on fallow fields to provide manure for increased soil fertility. This practice has strong environmental value, as the physical and chemical properties of the soil are enhanced and farmers can reduce reliance on expensive synthetic fertiliser. The prevalence of footrot, and consequent reduced mobility of livestock, would have constrained the adoption of this practice. A trial conducted by the Lumle Agricultural Research Centre, outlined by Subedi et al. (1990), indicated that in situ manuring increased per hectare maize production by 29% over straight application of purchased manure. The difference was thought to be derived from sheep urination during in situ manuring. Sheep urine has six times the nitrogen content and up to six times the potash content of straight animal manure.

- The number of sheep has been falling in the migratory systems of Nepal, as more financially attractive forms of employment — such as tourism porters, have reduced the number of people associated with small ruminant flocking (Karki 1994; Tulachan 1999). In addition to these pressures, the presence of footrot and consequent nuisance it caused shepherds and migratory farmers, was thought to be responsible for a reduction in the number of sheep within the western districts of Nepal. A cost–benefit assessment of the footrot monitoring and treatment strategy before eradication (MADSAR 1995), suggested that the footrot treatment strategy in the 1980s had reduced the 3.2% per year decline in sheep populations within footrot areas. Eradication of the disease is therefore likely to further enhance the diversity of livestock grazing in the hills, by reducing the impact of footrot and retarding sheep population decline to a greater extent, and assisting farmers to maintain a traditional lifestyle. It should be noted that sheep and goats are often owned by poor, smallholder farmers who cannot to afford to rear large ruminants.

- It is difficult to quantify exactly how the footrot eradication projects impacted social equity objectives. The presence of footrot, however, reduced time available to villagers for other work while caring for lame sheep around the village (time spent cutting fodder, decreased time spent repairing terraces, spinning wool, making cloth and in some cases reduced attendance of children at school). The elimination of footrot and an expected increase in animal sale from the flock will result in increased income of the people owning sheep and goats, which will support the schooling of children or improve family health. In addition, increased flock output (such as wool) will strengthen the village spinning industry largely operated by women.

- Professional shepherds have benefited from the eradication of footrot as the disease made stock movement difficult and is likely to have reduced the income from tending sheep and goats. Professional shepherds have very low incomes and are generally poorly educated.

- Research and extension activities at the Lumle Agricultural Research Centre have been shown to have a large economic impact (MADSAR 1995). Before footrot eradication, considerable resources were being devoted to footrot monitoring and treatment, therefore reducing scientific input into other productive endeavours.

- As a result of collaboration associated with ACIAR projects AS2/1991/017 and AS2/1996/021, a large number of researchers has been trained, and institutional capacity for disease diagnosis and vaccine deployment developed. It is difficult to quantify the magnitude of economic benefits stemming from this project output, although technology developed within the Nepal projects could be potentially used in Australia.

4. Benefit–cost Analysis of the Projects

In this section, project costs are initially outlined, then project benefit estimation assumptions provided. The section is concluded with a presentation of benefit–cost analysis results and sensitivity analyses.

4.1 Evaluation Framework

Economic benefits and project costs are estimated over the period 1993–2022 (30 years). It is assumed that footrot would have remained endemic in Kaski, Lamjung and Manang districts in the absence of eradication. In addition to disease impacts in these areas, a small probability of the disease spreading to neighbouring Mustang, Gorkha, Myagdi and Baglung districts is included in the assessment framework.

Benefits and costs are discounted using a 5% discount rate. Internal rate of return, net present value and benefit–cost ratio investment criteria are also presented for each scenario. A benefit–cost ratio of greater than one and a positive net present value indicate that project benefits are greater than project costs.

4.2 Project Costs

Costs associated with project activities in Nepal and Australia are presented in Table 3. These costs are translated into 1996 dollar terms for the benefit–cost analysis using adjustment factors for inflation and totalled approximately $A1.5 million.

Table 3. Annual project costs

Year	ACIAR project costs (A$ nominal)	Other project costs (A$ nominal)	Total project costs (A$ nominal)
1993 (12 July 1992)	150,880		150,880
1994	145,362		145,362
1995	149,096		149,096
1996	92,873		92,873
1997	162,349	130,000	292,349
1998	160,608	128,000	288,608
1999	155,277	126,000	281,277
2000	120,000		120,000

4.3 Key Assumptions

Within this section, the assumptions underpinning the calculation of project benefits are provided. As previously noted, three benefit groups are estimated for each of the scenarios. The first relates to the benefits from not having to support a costly footrot treatment program. The second is the economic gains to farmers from reduced livestock mortality as a result of eradication, and the third, the economic value of increased meat and wool production.

4.3.1 Reduced costs of the footrot treatment strategy

Since 1975, the Nepalese footrot treatment strategy was based on inspection of individual animals, paring of feet to expose any lesions, and foot-bathing. The treatment program consumed scientist labour, tied up technical support staff and involved expenditures on consumables such as procaine penicillin and streptomycin. The annual cost of the treatment program varied in accordance with the intensity of treatment and coverage of flocks in the target area. During 1983–1990, the number of small ruminants monitored varied from 25,685 in 1985 to 7,764 in 1989, while the most livestock (121,251) were treated in 1984 (Abington and Rasali 1994).

It is estimated that $A40,000 would have been spent each year (1994–2022) on treatment in the event that eradication was not achieved, as treatment intensity is assumed to be maintained at early 1990s levels (derived from MADSAR, 1995). Given this assumption, eradication is estimated to generate $A40,000 per year in reduced treatment costs.

4.3.2 Reduced costs of livestock mortality

Before eradication, there were approximately 50,000 sheep and goats within footrot-infected areas of the Kaski, Lamjung and Manang districts. Karki (1994) indicated that mortality levels within acutely infected flocks could be as high as about 53% greater when compared with disease-free flocks. It is difficult to ascertain the actual increase in mortality for flocks with average levels of infection, as prevalence levels were constantly changing across the 1980s in response to environmental conditions and levels of treatment intensity.

Flock mortality was, however, considered to be higher within footrot-endemic districts, as lame stock are more prone to predation, and debilitation decreases overall animal health. It is estimated that footrot increased average sheep and goat flock mortality by 3.5% per year within endemic districts. Given that 50,000 animals were estimated to reside in footrot-infected areas, and the average replacement value of a small ruminant is $A100, a reduction in footrot mortality is calculated to generate an annual benefit of $A175,000. This value is included as the first year benefit from reduced animal mortality in the project benefit stream.

In addition to increased mortality within endemic areas, the disease could also spread to the neighbouring districts of Mustang, Gorkha, Myagdi and Baglung. There are approximately 330,000 sheep and goats in these districts. It is assumed that the probability of spread to these areas in any one year was 2%, cumulative across the benefit–cost evaluation period. Once established, it is estimated that the disease would spread at 5% per year through these districts.

4.3.3 Increased wool and meat production

The invasion of bacterium into livestock feet and consequent lameness results in reduced wool and meat production. Treatment of infected animals during the 1970s and 1980s by Lumle staff greatly reduced the number of animals suffering clinical disease. For example, Abington and Rasali (1994) reported that only 2.3% of the 4,339 animals vaccinated during 1978 were subsequently found to be lame. In the analysis it is estimated that 3.5% of sheep and goats in the disease-endemic districts of Nepal suffered lameness as a result of footrot during the 1980s. Given that 50,000 small stock are raised in these areas, 1,750 were calculated to suffer morbidity losses.

It is estimated that average per head wool production is reduced by 15% for lame stock. Given a wool price of $A1.2/kg, average per head wool production of 0.5 kg and the above level of morbidity (primarily sheep), wool losses attributable to footrot were estimated to be $A158 per year. With the eradication of footrot, this cost is avoided and included as a benefit for the ACIAR projects.

Meat production losses are realised on livestock that are marketed. In the case of sheep and goats, it is estimated that 15% of livestock are turned-off each year, footrot infected stock have a reduced average per head liveweight of 4 kg and the average farm-gate price for meat is $A1.7/kg. Given these estimates, the annual cost of reduced meat production was calculated to be $A1,785 before eradication. With the eradication of footrot, this cost is now avoided and is also included in the benefit stream for the ACIAR projects.

Similarly to the avoided mortality calculation, meat and wool losses are also estimated, assuming that footrot could have spread to neighbouring districts. As noted above, approximately 330,000 sheep and goats reside in these districts. It is assumed that the probability of spread to these areas in any one year was 2%, cumulative across the benefit–cost evaluation period. Once established in these districts it is estimated that the disease would spread at 5% per year.

By combining avoided treatment costs with reduced mortality and increased meat and wool production benefits the first year annual benefit of the eradication projects in Nepal has been estimated to be $A0.23 million. By factoring in the potential for disease spread, the annual benefit increased to $A0.29 million by the end of the forecast period (Figure 3).

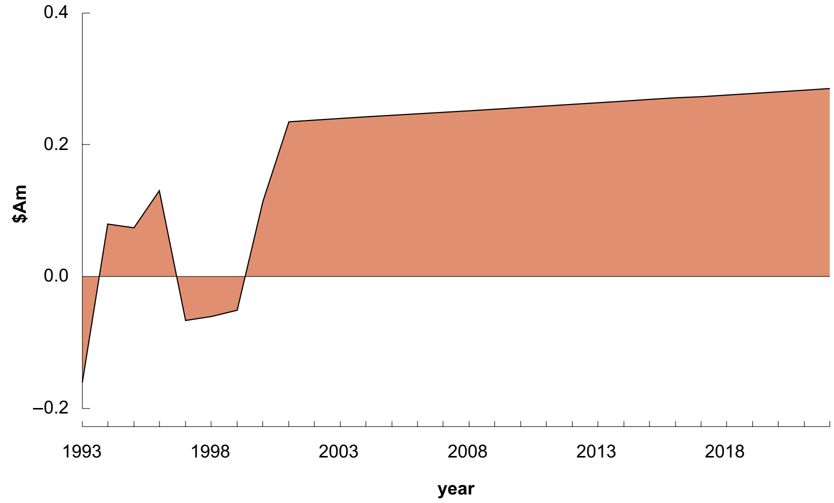

Figure 3. Project net benefits through time

4.4 Results

The net present value (NPV) of footrot eradication in Nepal is forecast to be $A2.8 million expressed in 1996 dollar terms and at a discount rate of 5%. The corresponding benefit–cost ratio was estimated to be 2.9:1. A benefit–cost ratio of this magnitude suggests that for each dollar allocated to the projects 2.9 dollars of project benefits will be generated.

The present value of project benefits and net present values are outlined in Table 4. It is apparent that a present value of benefits of $A4.3 million would accrue to the projects and the projects have cost $1.5 million in discounted terms.

Table 4. Present value of benefits

Investment criteria	
Present value of benefits (A$ million)	Net present value (NPV) (A$ million)
4.3	2.8

Most of the estimated aggregate project benefits have been captured by smallholder farmers in Nepal. It was calculated that 84% of benefits will be reaped by farmers through reduced livestock mortality and production losses, while the remaining 16% of benefits result from reduced footrot management costs (Table 5).

4.5 Sensitivity Analysis

Several estimates have been included in the analysis in relation to the impact of footrot eradication in Nepal. These estimates have been made using the best available information, but are uncertain. Sensitivity analysis is undertaken in this section to determine which parameters have a significant impact upon the estimated economic returns of the projects. Possible economic benefits to Australia from investment in ACIAR projects AS2/1991/017 and AS2/1996/021 are also assessed.

4.5.1 Discount rate

A 5% discount rate was included in the analysis for baseline economic return calculations. The appropriate magnitude of this parameter may vary for different investors. Consequently, the sensitivity of net present value and benefit–cost ratios to the discount rate used are outlined in Table 6.

Higher benefit–cost ratios and net present values are calculated at lower discount rates. The difference between net present values at 5 and 10% discount rates is calculated to be $A1.3 million.

4.5.2 Reduced probability of footrot spread

It is assumed that the disease could have spread to the neighbouring districts of Mustang, Gorkha, Myagdi and Baglung. Further, it was estimated that the probability of spread to these areas in any one year was 2%. A great deal of uncertainty surrounds the exact nature of this parameter. Correspondingly, the sensitivity of investment returns to increases in the probability of spread are presented in Table 7.

Table 5. Benefit–cost analysis

Period		Benefits					Research	Totals	
Year no.	Year (date)	Nepal control benefits (A$nom)	Nepal farmer benefits (A$nom)	Adjust factor	Nepal benefits (A$1996)	Gross benefits (A$)	Total costs (A$1996)	Net benefits (A$1996)	Net present value (A$1996)
1	1993	0.00	0.00	1.07	0.00	0.00	0.16	–0.16	–0.19
2	1994	0.04	0.18	1.06	0.23	0.23	0.15	0.08	0.09
3	1995	0.04	0.18	1.03	0.23	0.23	0.15	0.07	0.08
4	1996	0.04	0.18	1	0.22	0.22	0.09	0.13	0.13
5	1997	0.04	0.19	1	0.23	0.23	0.29	–0.07	–0.06
6	1998	0.04	0.19	1	0.23	0.23	0.29	–0.06	–0.05
7	1999	0.04	0.19	1	0.23	0.23	0.28	–0.05	–0.04
8	2000	0.04	0.19	1	0.23	0.23	0.12	0.11	0.09
9	2001	0.04	0.20	1	0.24	0.24	0.00	0.24	0.18
10	2002	0.04	0.20	1	0.24	0.24	0.00	0.24	0.18
11	2003	0.04	0.20	1	0.24	0.24	0.00	0.24	0.17
12	2004	0.04	0.20	1	0.24	0.24	0.00	0.24	0.16
13	2005	0.04	0.20	1	0.24	0.24	0.00	0.24	0.16
14	2006	0.04	0.21	1	0.25	0.25	0.00	0.25	0.15
15	2007	0.04	0.21	1	0.25	0.25	0.00	0.25	0.15
16	2008	0.04	0.21	1	0.25	0.25	0.00	0.25	0.14
17	2009	0.04	0.21	1	0.25	0.25	0.00	0.25	0.13
18	2010	0.04	0.22	1	0.26	0.26	0.00	0.26	0.13
19	2011	0.04	0.22	1	0.26	0.26	0.00	0.26	0.12
20	2012	0.04	0.22	1	0.26	0.26	0.00	0.26	0.12
21	2013	0.04	0.22	1	0.26	0.26	0.00	0.26	0.12
22	2014	0.04	0.23	1	0.27	0.27	0.00	0.27	0.11
23	2015	0.04	0.23	1	0.27	0.27	0.00	0.27	0.11
24	2016	0.04	0.23	1	0.27	0.27	0.00	0.27	0.10
25	2017	0.04	0.23	1	0.27	0.27	0.00	0.27	0.10
26	2018	0.04	0.24	1	0.28	0.28	0.00	0.28	0.09
27	2019	0.04	0.24	1	0.28	0.28	0.00	0.28	0.09
28	2020	0.04	0.24	1	0.28	0.28	0.00	0.28	0.09
29	2021	0.04	0.24	1	0.28	0.28	0.00	0.28	0.08
30	2022	0.04	0.25	1	0.29	0.29	0.00	0.29	0.08
Total		1.16	6.14		7.32	7.32	1.54	5.78	2.81

Table 6. Sensitivity of investment criteria to discount rate

Investment criteria	Discount rate		
	0%	5%	10%
Net present value ($A million) Benefit–cost ratio	5.8 4.7:1	2.8 2.9:1	1.5 2.0:1

Table 7. Sensitivity of investment criteria to probability of spread

Investment criteria	Probability of spread		
	(0%)	(2%) Base	(4%)
Net present value ($A million) Benefit–cost ratio	2.4 2.6:1	2.8 2.9:1	3.2 3.2:1

It is evident that an increase in the probability of spread by 2% increases net present value by $A0.4 million. Even without the incorporation of disease spread in the analysis, the projects generate positive economic benefits.

4.5.3 Adoption of a vaccination-strategy in Australia

Within Australia, footrot has been estimated to cost $60–100 million per year, primarily owing to wool losses and treatment costs. Currently, control of footrot in Australia is based on zoning, quarantine, foot-bathing and the limited use of vaccines — with management varying on a State by State basis. In New South Wales, a comprehensive industry-funded campaign has been under way since 1988. The number of infected flocks has been reduced from more than 5000 to less than 500.

Early in the NSW program, a vaccine-based approach was used extensively as a component of a package of disease control techniques. It is scarcely used at all now. At this late stage of the program some problems are emerging. Some strains of the organism which are less than fully virulent are more difficult to eliminate. It is in these flocks where there is now an interest in using specific vaccination in the light of the work funded by ACIAR in Nepal.

Footrot is widespread in Victoria and Tasmania. There is a potential in these two important sheep States to reassess the place of vaccination in footrot management. In the past, vaccines have been formulated with all the known serogroups. As a consequence they were expensive and, because of a phenomenon known as antigenic competition, not very potent. The work in Nepal and Bhutan will provide an incentive to examine the place of highly potent, specific vaccines. Footrot also occurs in Western Australia and South Australia but it is not widespread because of the less favourable environments. Vaccine use is not encouraged by the authorities in those two States.

The demonstration in Nepal that targeted vaccination could eradicate the disease may help formulate an appropriate vaccination strategy for some parts of Australia. It is very difficult to determine the exact nature of any spin-back benefits to Australia. If, however, a footrot vaccination program (as an aid to footrot management) were implemented in Australia after 2010, footrot costs were reduced by $30 million per year and 10% of strategy formulation could be traced back to experiences in the ACIAR projects, then substantial economic benefits (Table 8) would be generated.

Table 8. Sensitivity of investment criteria to possible benefits in Australia

Investment criteria	Level of benefits attributable to ACIAR projects		
	0%	15%	20%
Net present value ($A million)	2.8	16.2	29.7
Benefit–cost ratio	2.9:1	11.9:1	20.9:1

5. Conclusions

Footrot was endemic in the western districts of Nepal. As a result of the ACIAR projects AS2/1991/017 and AS2/1996/021, this disease has been eradicated from the livestock industries of this country. By factoring in the probability for spread into the project benefit stream, the economic attractiveness of the projects substantially increases. At a 5% discount rate, the net present value of the projects was estimated to be $A2.8 million and a benefit–cost ratio of 2.9:1 was forecast.

In addition to the benefit–cost estimates, there are several non-economic benefits that have stemmed from research activities. These include environmental benefits, biodiversity enhancement, social equity improvement and research capacity development. These benefits are not quantified in the analysis, but are major outcomes of the projects.

The ACIAR projects are likely to have flow-back benefits for Australia as it has been demonstrated that specific footrot vaccination works, along with blood tests being shown to be useful in assessing disease prevalence and providing evidence of disease freedom. These tests are now being actively investigated in Australia. There are barriers in Australia to use of this technology, principally the existence of a greater number of serogroups than in Nepal, but this problem is not insurmountable. There was little or no support in Australia for these ideas before the success of the ACIAR projects.

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7. References

Abington, J.B. and Rasali, D.P. 1994. Footrot eradication programme in sheep and goats: an historical development in Nepal. In: Rasali, D.P., ed., Proceedings of the seminar on footrot eradication in sheep and goats in Nepal. Kaski, Nepal, Lumle Agricultural Research Station, Occasional Paper No. 94/1.

ADB (Asian Development Bank) 1993. Nepal Livestock Master Plan — Volume 3, the livestock sector. Consultant report prepared by ANZDEC Limited, ADB June 1993.

Bain, R., Joshi, B. and Gauchan, D. 2000. Nepal assessment report — development and testing of an integrated approach to the control of gastro-intestinal parasites of small ruminants in South and Southeast Asia (TAG 433). Report and findings of a consultancy to examine the importance of helminth infections as a constraint to the sustainable livelihoods of small ruminant producers in Nepal, International Livestock Research Institute, April.

Carmody, M.J. 1981. The economic evaluation of the footrot eradication plan in the Northern Tablelands of NSW. Agricultural Economics Bulletin (Armidale, NSW), No. 25.

Egerton, J.R. 1991. Project proposal: Control of footrot in small-ruminants in Nepal. Canberra, ACIAR Project No. PN 9117.

Egerton, J.R., Joshi, B.R., Dhungyel, O.P. and Whittington, R.J. 2000. Final report: Control of footrot in small-ruminants in Nepal — vaccination and sero surveillance, ACIAR Project No. AS2/96/21, ACIAR, Canberra.

Egerton, J.R., Roberts, D.J. and Parsonson, I.M. 1969. The aetiology and pathogenesis of ovine footrot — a histological study of the bacterial invasion. Journal of Comparative Pathology, 79, 207–216.

FAO (Food and Agriculture Organization of the United Nations) 2000. Livestock statistics. Rome, FAO. (http://apps.fao.org/cgi-bin/nph-db)

Ghimire, S.C. 1994. Epidemiological study on footrot transmission in the migratory flocks of Nepal. Kaski, Nepal, Lumle Agricultural Research Centre, Working Paper No. 94/56.

Ghimire, S.C. and Egerton, J.R. 1994. Current status report on footrot disease investigation at Lumle Agricultural Research Centre. In: Rasali, D.P., ed., Proceedings of the seminar on footrot eradication in sheep and goats in Nepal. Kaski, Nepal, Lumle Agricultural Research Station, Occasional Paper No. 94/1.

Ghimire, S.C., Egerton, J.R. and Dhungyel, O.P. 1996. Characterisation of *Dichelobacter nodous* from footrot in Nepal. Small Ruminant Research, 23, 59–67.

Jordan, D. and Karki, N.P. 1999. ACIAR project review — Control of footrot in small-ruminants in Nepal – vaccination and sero surveillance. ACIAR Project No. AS2/96/21, ACIAR, Canberra.

Karki, N.P.S. 1985. Migratory system of sheep raising in Gandaki Zone of Nepal. In: Morel, A.M. and Oli, K.P., ed., Livestock production in the hills of Nepal. Dhankuta, Nepal, Pakhribas Agricultural Centre, 50–61.

Karki, N.P.S. 1994. Footrot eradication programme — problems and achievements in Nepal. In: Rasali, D.P., ed., Proceedings of the seminar on footrot eradication in sheep and goats in Nepal. Kaski, Nepal, Lumle Agricultural Research Station, Occasional Paper No. 94/1.

MADSAR 1995. The social and economic impact of research done at Lumle and Pakhribas Agricultural Centres in Nepal. MASDAR and the Overseas Development Group, University of East Anglia — Report to the Overseas Development Administration (ODA), United Kingdom, June.

Pradhan, S.L. 2000. Livestock development in Nepal — future challenges, development concepts and approaches. In: Sherchand, L., Pradhan, B.R., Bhurtel, R. and Nepane, S.P., ed. Proceedings of the Third National Animal Science Convention, 27–28 August 2000. Kathmandu, Nepal, Nepal Animal Science Association.

Shrestha, H.R. and Pradhan, D.R. 1995. Research priorities for animal agriculture by agro-ecological zone in Nepal. In: Devendra, C. and Gardiner, P., ed., Global agenda for livestock research. Proceedings of the consultation for the South Asia region. Kenya, International Livestock Research Institute, 85–102.

Subedi, K.D., Joshi, K.D. and Dital, B.K. 1990. In-situ manuring by sheep proved better than the application of sheep manure. Prabidhi Sangalo (Nepali version), 16(4), 5.

Tulachan, P.M. 1999. Livestock in mixed faming systems of the Hindu Kush-Himalayas – trends and sustainability. FAO, Rome, International Centre for Integrated Mountain Development, 116p.

Whittington, R.J. and Pradhan, S.M.S. 1994. ACIAR project review — Control of footrot in small-ruminants in Nepal. Canberra, ACIAR Project No. PN9117.

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